AMENDMENTS TO THE CLAIMS

The listing of claims below replaces all prior versions of claims in the application.

1. (Currently Amended): A method for designing industrial products by using a computer, comprising:

generating a three-dimensional clothoid curve <u>by the computer</u>; and

designing a shape of said industrial products based on the three-dimensional clothoid curve <u>by the computer</u>,

wherein each of a pitch angle and a yaw angle in a tangential direction of said three-dimensional clothoid curve is given by a quadratic expression comprising of a curve length or a curve length variable.

2. (Previously Presented): The method for designing industrial products according to claim 1, wherein:

the industrial products being a machine including a mechanism in which a mechanical element having a mass moves and

a trajectory of motion of the mechanical element is designed by using the three-dimensional curve (referred to as the three-dimensional clothoid curve).

3. (Currently Amended): The method for designing industrial products according to claim 2, wherein:

the machine is a screw device including a mechanism in which a ball as the mechanical element moves,

the screw device comprises a screw shaft having an outer surface on which a spiral rolling element rolling groove is formed, a nut having an inner surface on which a load rolling element rolling groove is formed so as to be opposed to the rolling element rolling groove and a regression path is formed to connect a one end and the other end of the load rolling element rolling groove, and a plurality of rolling elements disposed between the rolling element rolling groove of the screw shaft and the load rolling element rolling groove of the nut and disposed in the regression path, and

the regression path of the screw device is designed by using the three-dimensional curve ~~(referred to as the three-dimensional clothoid curve)~~.

4. (Previously Presented): The method for designing industrial products according to claim 1, wherein the three-dimensional clothoid curve contain expressions,

$$P = P_0 + \int_0^s u ds = P_0 + h \int_0^S u dS, \quad 0 \le s \le h, \quad 0 \le S = \frac{s}{h} \le 1$$

(1);

$$u = E^{k\beta}E^{j\alpha}(i) = \begin{bmatrix} \cos\beta & \sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} \cos\beta\cos\alpha \\ \sin\beta\cos\alpha \\ -\sin\alpha \end{Bmatrix}$$

(2);

$$\alpha = a_0 + a_1 S + a_2 S^2$$ (3);

$$\beta = b_0 + b_1 S + b_2 S^2 \qquad (4),$$

wherein

$$P = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}, \quad P_0 = \begin{Bmatrix} x_0 \\ y_0 \\ z_0 \end{Bmatrix} \qquad (5)$$

shows a positional vector at each point on the three-dimensional clothoid curve and its initial value, respectively, the expressions for the three-dimensional clothoid curve when implemented:

assumes that the length of the curve from a starting point is s and its whole length (a length from the starting point to an end point) is h, and produces a dimensionless value S, which is called the curve length variable;

i, j and k are unit vectors in the x-axis, y-axis and z-axis directions, respectively; and

the u is a unit vector showing a tangential direction of the curve at a point P, which is given by the Expression (2) and the $E^{k\beta}$ and the $E^{j\alpha}$ are rotation matrices and represent an angular rotation of angle β about the k-axis and an angular rotation of angle α about the j-axis, respectively,

wherein the $E^{k\beta}$ is referred to as a yaw rotation, while the $E^{j\alpha}$ is referred to as a pitch rotation and the Expression (2) means that the unit vector in the i-axis direction is rotated by an angle α about the j-axis, before being rotated by an angle β about the k-axis, thus producing a tangent vector u in which a_0, a_1, a_2, b_0, b_1 and b_2 are constants.

5. (Previously Presented): The method for designing industrial products according to claim 4, wherein a plurality of spatial points are specified in a three-dimensional coordinate system and these spatial points are interpolated by using the three-dimensional clothoid curve, whereby the shape of the industrial product is designed.

6. (Currently Amended): The method for designing industrial products according to claim 5, wherein the seven parameters a_0, a_1, a_2, b_0, b_1, b_2 and h of the three-dimensional clothoid segments are calculated so that, between a one three-dimensional clothoid segment (a unit curve consisting of a group of curves produced on the interpolation) and the next three-dimensional clothoid segment (a unit curve consisting of a group of curves produced on the interpolation), positions, tangential directions, normal directions, and curvatures of both the one and next three-dimensional clothoid segments are made continuous to each other, respectively, at the plurality of spatial points.

7. (Previously Presented): The method for designing industrial products according to claim 6, wherein:

the seven parameters a_0, a_1, a_2, b_0, b_1, b_2 and h of the three-dimensional clothoid segments are calculated by making the number of conditional expressions produced by mutual addition to be made between conditional expressions concerning the tangential directions, the normal directions and the curvatures at both the starting point and the end point and further conditional

expressions allowing the positions, the tangential directions, the normal directions, and the curvatures of both the one and next three-dimensional clothoid segments to be made continuous to each other, respectively, at the plurality of spatial points agree with the unknowns of the seven parameters a_0, a_1, a_2, b_0, b_1, b_2 and h of the three-dimensional clothoid segments, whereby the conditional expressions is made agree with the unknowns in terms of number thereof, by specifying the tangential directions, the normal directions and the curvatures at the stating point and the and point among the plurality of spatial points and additionally inserting objective points being interpolated between the spatial points which have been specified in advance.

8. (Cancelled).

9. (Previously Presented): A data storage device characterized in that:

the data storage device contains program for designing a shape of an industrial product which, when executed by a computer, implements,

a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression comprising of a curve length or a curve length variable.

10. (Previously Presented): A computer-readable recording medium, which is for designing a shape of an industrial product, recording thereon a program enabling a computer to operate as means to design the shape of the industrial product by using a three-dimensional curve

(referred to as a three-dimensional clothoid curve) in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression comprising of a curve length or a curve length variable.

11. (Withdrawn): A numerical control method expressing a trajectory of a machine tool or a contour shape of a workpiece by using a three-dimensional curve (referred to as a three-dimensional clothoid curve) in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling motion of the machine tool based on the three-dimensional curve.

12. (Withdrawn): The numerical control method according to claim 11, wherein the three-dimensional clothoid contain expressions,

$$P = P_0 + \int_0^s u\,ds = P_0 + h\int_0^S u\,dS, \quad 0 \le s \le h, \quad 0 \le S = \frac{s}{h} \le 1 \qquad (1);$$

$$u = E^{k\beta}E^{j\alpha}(i) = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} \cos\beta\cos\alpha \\ \sin\beta\cos\alpha \\ -\sin\alpha \end{Bmatrix} \qquad (2);$$

$$\alpha = a_0 + a_1 S + a_2 S^2 \qquad (3);$$

$$\beta = b_0 + b_1 S + b_2 S^2 \qquad (4),$$

wherein,

$$P = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}, \quad P_0 = \begin{Bmatrix} x_0 \\ y_0 \\ z_0 \end{Bmatrix} \qquad (5)$$

shows a positional vector at each point on the three-dimensional clothoid curve and its initial value, respectively, the expressions for the three-dimensional clothoid curve when implemented:

assumes that the length of the curve from a starting point is s and its whole length (a length from the starting point to an end point) is h, and produces a dimensionless value S, which is called the curve length variable;

i, j and k are unit vectors in the x-axis, y-axis and z-axis directions, respectively; and

the u is a unit vector showing a tangential direction of the curve at a point P, which is given by the Expression (2) and the Ek^{β} and the $E^{j\alpha}$ are rotation matrices and represent an angular rotation of angle β about the k-axis and an angular rotation of angle α about the j-axis, respectively;

wherein the $E^{k\beta}$ is referred to as a yaw rotation, while the $E^{j\alpha}$ is referred to as a pitch rotation and the Expression (2) means that the unit vector in the i-axis direction is rotated by an angle α about the j-axis, before being rotated by an angle β about the k-axis, thus producing a tangent vector u in which a_0, a_1, a_2, b_0, b_1 and b_2 are constants.

13. (Withdrawn): A numerical control device expressing a trajectory of a machine tool or a contour shape of a workpiece by using a three-dimensional curve (referred to as a three-dimensional clothoid curve) in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling motion of the machine tool based on the three-dimensional curve.

14. (Withdrawn): A data storage device characterized in that:

the data storage device contains program for numerically controlling motion of a machine tool which, when executed by a computer to express a trajectory of the machine tool, implements

a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable.

15. (Withdrawn): A computer-readable recoding medium, which is for numerically controlling motion of a machine tool, recording thereon a program enabling a computer to operate as means to express a trajectory of the machine tool by using a three-dimensional curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable, or results computed based on the program.

16. (Withdrawn): A numerical control method comprising steps of interpolating points of a row of points arbitrarily given in a three-dimensional coordinate by using a three-dimensional curve (referred to as three-dimensional clothoid segments) in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling motion of a machine tool based on the three-dimensional clothoid segments.

17. (Withdrawn): A numerical control method comprising steps of mutually connecting a plurality of three-dimensional clothoid curves (each of which is referred to as three-dimensional clothoid segments) in each of which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling motion of a machine tool based on the plural three-dimensional clothoid segments.

18. (Withdrawn): The numerical control method according to claim 16, wherein the three-dimensional clothoid curve contain expressions,

$$P = P_0 + \int_0^s u\,ds = P_0 + h\int_0^S u\,dS, \quad 0 \le s \le h, \quad 0 \le S = \frac{s}{h} \le 1$$

(1);

$$u = E^{k\beta}E^{j\alpha}(i) = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} \cos\beta\cos\alpha \\ \sin\beta\cos\alpha \\ -\sin\alpha \end{Bmatrix}$$

(2);

$$\alpha = a_0 + a_1 S + a_2 S^2 \qquad (3);$$

$$\beta = b_0 + b_1 S + b_2 S^2 \qquad (4);$$

wherein,

$$P = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}, \quad P_0 = \begin{Bmatrix} x_0 \\ y_0 \\ z_0 \end{Bmatrix} \qquad (5)$$

shows a positional vector at each point on the three-dimensional clothoid curve and its initial value, respectively, the expressions for the three-dimensional clothoid curve when implemented:

assumes that the length of the curve from a starting point is s and its whole length (a length from the starting point to an end point) is h, and produces a dimensionless value S, which is called the curve length variable;

i, j and k are unit vectors in the x-axis, y-axis and z-axis directions, respectively; and

the u is a unit vector showing a tangential direction of the curve at a point P, which is given by the Expression (2) and the $E^{k\beta}$ and the $E^{j\alpha}$ are rotation matrices and represent an angular rotation of angle β about the k-axis and an angular rotation of angle α about the j-axis, respectively,

wherein the $E^{k\beta}$ is referred to as a yaw rotation, while the $E^{j\alpha}$ is referred to as a pitch rotation and the Expression (2) means that the unit vector in the i-axis direction is rotated by an

angle α about the j-axis, before being rotated by an angle β about the k-axis, thus producing a tangent vector u in which a0, a_1, a_2, b_0, b_1 and b_2 are constants.

19. (Withdrawn): The numerical control method according to claim 18, characterized in that the seven parameters a_0, a_1, a_2, b_0, b_1, b_2 and h are calculated in such a manner that, at a connecting point between, of the plural three-dimensional clothoid segments, a single three-dimensional clothoid segment and the next three-dimensional clothoid segment thereto, positions and tangential directions (and in some cases, curvatures) of both three-dimensional clothoid segments are continuous, respectively.

20. (Withdrawn): A numerical control device interpolating points of a row of points arbitrarily given in a three-dimensional coordinate by using a three-dimensional curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling motion of a machine tool based on the three-dimensional clothoid segments.

21. (Withdrawn): A data storage device characterized in that:

the data storage device contains program for numerically controlling motion of a machine tool which, when executed by the computer to operate as means to interpolate points of a row of points arbitrarily given in a three-dimensional coordinate, implements

a three-dimensional curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable and controlling the motion of the machine tool based on the three-dimensional clothoid segments.

22. (Withdrawn): A computer-readable recording medium, which is for numerically controlling motion of a machine tool, recording either a program enabling a computer as means for interpolating points of a row of points arbitrarily given in a three-dimensional coordinate by using a three-dimensional curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable, or results calculated on the program.

23. (Withdrawn): A numerical control method comprising steps of

expressing a trajectory of a machine tool by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

specifying motion of the machine tool to be moved along the three-dimensional curve, and

calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

24. (Withdrawn): The numerical control method according to claim 23, wherein the three-dimensional clothoid curve contain expressions,

$$P = P_0 + \int_0^s u\,ds = P_0 + h\int_0^S u\,dS, \quad 0 \le s \le h, \quad 0 \le S = \frac{s}{h} \le 1$$

(1);

$$u = E^{k\beta}E^{j\alpha}(i) = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix}\begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} \cos\beta\cos\alpha \\ \sin\beta\cos\alpha \\ -\sin\alpha \end{Bmatrix}$$

(2);

$$\alpha = a_0 + a_1 S + a_2 S^2 \qquad (3);$$

$$\beta = b_0 + b_1 S + b_2 S^2 \qquad (4);$$

wherein,

$$P = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}, \quad P_0 = \begin{Bmatrix} x_0 \\ y_0 \\ z_0 \end{Bmatrix} \qquad (5)$$

shows a positional vector at each point on the three-dimensional clothoid curve and its initial value, respectively, the expressions for the three-dimensional clothoid curve when implemented:

assumes that the length of the curve from a starting point is s and its whole length (a length from the starting point to an end point) is h, and produces a dimensionless S, which is called the curve length variable;

i, j and k are unit vectors in the x-axis, y-axis and z-axis directions, respectively; and

the u is a unit vector showing a tangential direction of the curve at a point P, which is given by the Expression (2) and the $E^{k\beta}$ and the $E^{j\alpha}$ are rotation matrices and represent an angular rotation of angle β about the k-axis and an angular rotation of angle α about the j-axis, respectively,

wherein the $E^{k\beta}$ is referred to as a yaw rotation, while the $E^{j\alpha}$ is referred to as a pitch rotation and the Expression (2) means that the unit vector in the i-axis direction is rotated by an angle α about the j-axis, before being rotated by an angle β about the k-axis, thus producing a tangent vector u in which a0, a_1, a_2, b_0, b_1 and b_2 are constants.

25. (Withdrawn): A numerical control device which is configured to

express a trajectory of a machine tool by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

specify motion of the machine tool to be moved along the three-dimensional curve, and

calculate a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

26. (Withdrawn): A data storage device characterized in that:

program which, when executed by a computer for numerically controlling motion of a machine tool, implements,

means for expressing a trajectory of a machine tool by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

means for specifying motion of the machine tool to be moved along the three-dimensional curve, and

means for calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

27. (Withdrawn): A computer-readable recording medium, which is for numerically controlling motion of a machine tool, recording thereon a program enabling a computer to operate as

means for expressing a trajectory of a machine tool by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

means for specifying motion of the machine tool to be moved along the three-dimensional curve, and

means for calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

28. (Withdrawn): The numerical control method according to claim 17, wherein the three-dimensional clothoid curve contain expressions,

$$P = P_0 + \int_0^s u\,ds = P_0 + h\int_0^S u\,dS, \quad 0 \le s \le h, \quad 0 \le S = \frac{s}{h} \le 1$$

(1);

$$u = E^{k\beta}E^{j\alpha}(i) = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} \cos\beta\cos\alpha \\ \sin\beta\cos\alpha \\ -\sin\alpha \end{Bmatrix}$$

(2);

$$\alpha = a_0 + a_1 S + a_2 S^2 \qquad (3);$$

$$\beta = b_0 + b_1 S + b_2 S^2 \qquad (4);$$

wherein,

$$P = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}, \quad P_0 = \begin{Bmatrix} x_0 \\ y_0 \\ z_0 \end{Bmatrix} \qquad (5)$$

shows a positional vector at each point on the three-dimensional clothoid curve and its initial value, respectively, the expressions for the three-dimensional clothoid curve when implemented:

assumes that the length of the curve from a starting point is s and its whole length (a length from the starting point to an end point) is h, and produces a dimensionless value S, which is called the curve length variable;

i, j and k are unit vectors in the x-axis, y-axis and z-axis directions, respectively; and

the u is a unit vector showing a tangential direction of the curve at a point P, which is given by the Expression (2) and the $E^{k\beta}$ and the $E^{j\alpha}$ are rotation matrices and represent an angular rotation of angle β about the k-axis and an angular rotation of angle α about the j-axis, respectively,

wherein the $E^{k\beta}$ is referred to as a yaw rotation, while the $E^{j\alpha}$ is referred to as a pitch rotation and the Expression (2) means that the unit vector in the i-axis direction is rotated by an angle α about the j-axis, before being rotated by an angle β about the k-axis, thus producing a tangent vector u in which a0, a_1, a_2, b_0, b_1 and b_2 are constants.

29. (Withdrawn): A data storage device characterized in that:

the data storage device contains program for numerically controlling motion of a machine tool which, when executed by a computer to contour shape of a workpiece, implements

a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable.

30. (Withdrawn): A computer-readable recoding medium, which is for numerically controlling motion of a machine tool, recording thereon a program enabling a computer means to contour shape of a workpiece by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable, or results computed based on the program.

31. (Withdrawn): A numerical control method comprising steps of:

expressing a contour shape of a workpiece by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

specifying motion of a machine tool to be moved along the three-dimensional curve, and

calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

32. (Withdrawn): A numerical control device which is configured to

express a contour shape of a workpiece by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

specify motion of a machine tool to be moved along the three-dimensional curve, and

calculate a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

33. (Withdrawn): A data storage device characterized in that:

the data storage device contains program which, when executed by a computer for numerically controlling motion of a machine tool, implements

means for expressing a trajectory of a contour shape of a workpiece by using a three-dimensional clothoid curve in which each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

means for specifying motion of the machine tool to be moved along the three-dimensional curve, and

means for calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.

34. (Withdrawn): A computer-readable recording medium, which is for numerically controlling motion of a machine tool, recording thereon a program enabling a computer to operate as

means for expressing a contour shape of a workpiece by using a three-dimensional clothoid curve wherein each of a pitch angle and a yaw angle in a tangential direction is given by a quadratic expression of a curve length or a curve length variable,

means for specifying motion of the machine tool to be moved along the three-dimensional curve, and

means for calculating a moved position of the machine tool at unit-time intervals according to the specified motion,

wherein the motion is defined as positional information changing as a function of time.